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Title: Smart Mobile Sensor Platform Development for Radiological Mapping of Large-scale Areas

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Smart Mobile Sensor Platform Development for Radiological Mapping of Large-Scale Areas

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Motivation

Timely and accurate characterization of radiation contamination in large-scale areas

Survey routes typically use uniform scanning of area

Advances in autonomous mobile platforms (unmanned aerial/ground vehicles)

→ attach radiation sensors

Move away from uniform survey routes to save time while maintaining accurate mapping capabilities

Technical Approach

1. Develop full-mapping capability with sparse observations to alleviate necessity for uniform scanning routes

   → ML regression technique (Gaussian Process Regression, GPR) to predict contamination in unvisited locations

2. Leverage full-mapping capability to inform optimal motion planning of mobile radiation detectors (Voronoi partition optimization)

   → Recursively update optimal next-iteration measurement location based on observations

Gaussian Process Regression (GPR) model

For our application, the training data represented as

$$(\mathbf{X} = (\mathbf{x_1},\ldots,\mathbf{x_n})^T,\ \mathbf{y} = (y_1,\ldots,y_n))$$

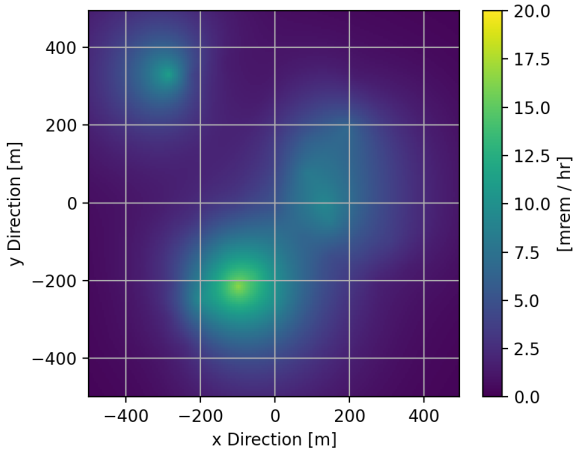
X contains features of the output data (n x 2 matrix with latitude and longitude)
y contains output of the data (n x 1 vector with radiation count rates)
Full GPR model defined as

$$\begin{pmatrix} y_* \\ y_1 \\ \vdots \\ y_n \end{pmatrix} \sim N\left(\mu=\begin{pmatrix} m(\boldsymbol{x_*}) \\ m(\boldsymbol{x_1}) \\ \vdots \\ m(\boldsymbol{x_n}) \end{pmatrix}, \Sigma=\begin{pmatrix} k_{**} & k_{*.} \\ k_{.*} & k_{..} \end{pmatrix}\right)$$

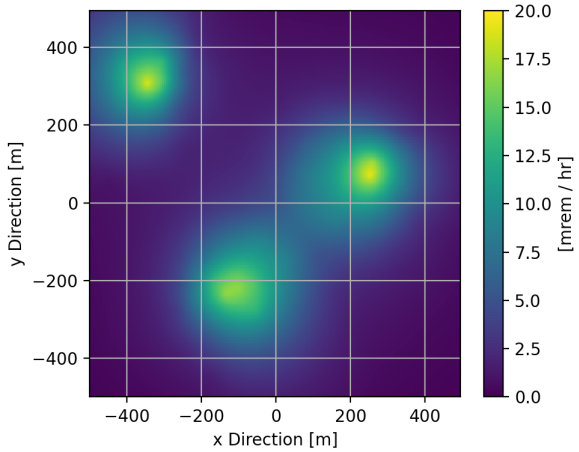
y_* is the radiation count rates we are predicting at $\mathbf{x}_*$ unvisited locations

Gaussian Process Regression (GPR) mapping

Predicts contamination in entire area for every set of observations



Prior prediction

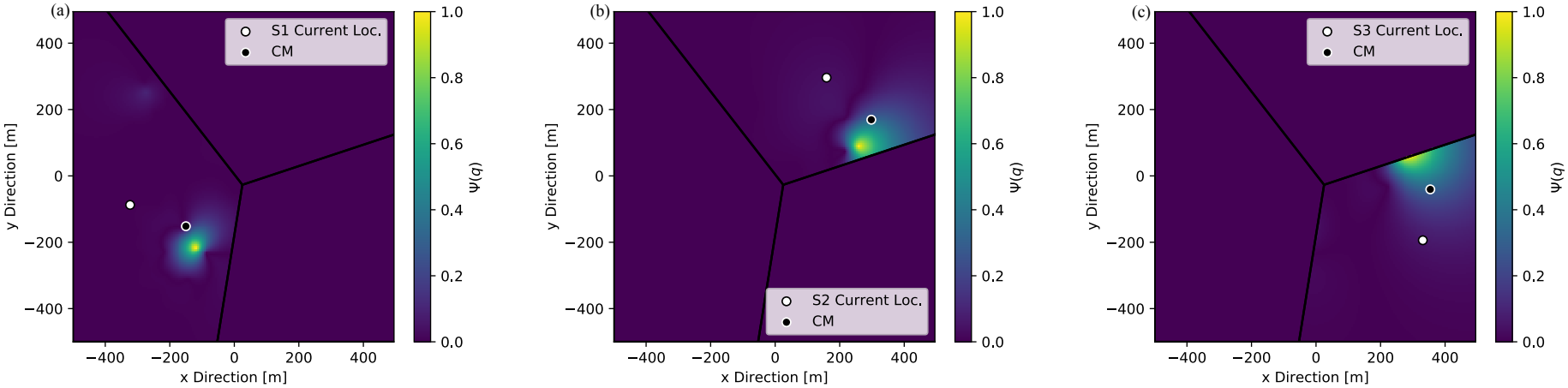


Current prediction

Calculate difference between prior and current predictions

Voronoi partition for optimized area coverage

Area of interest is divided into Voronoi cells

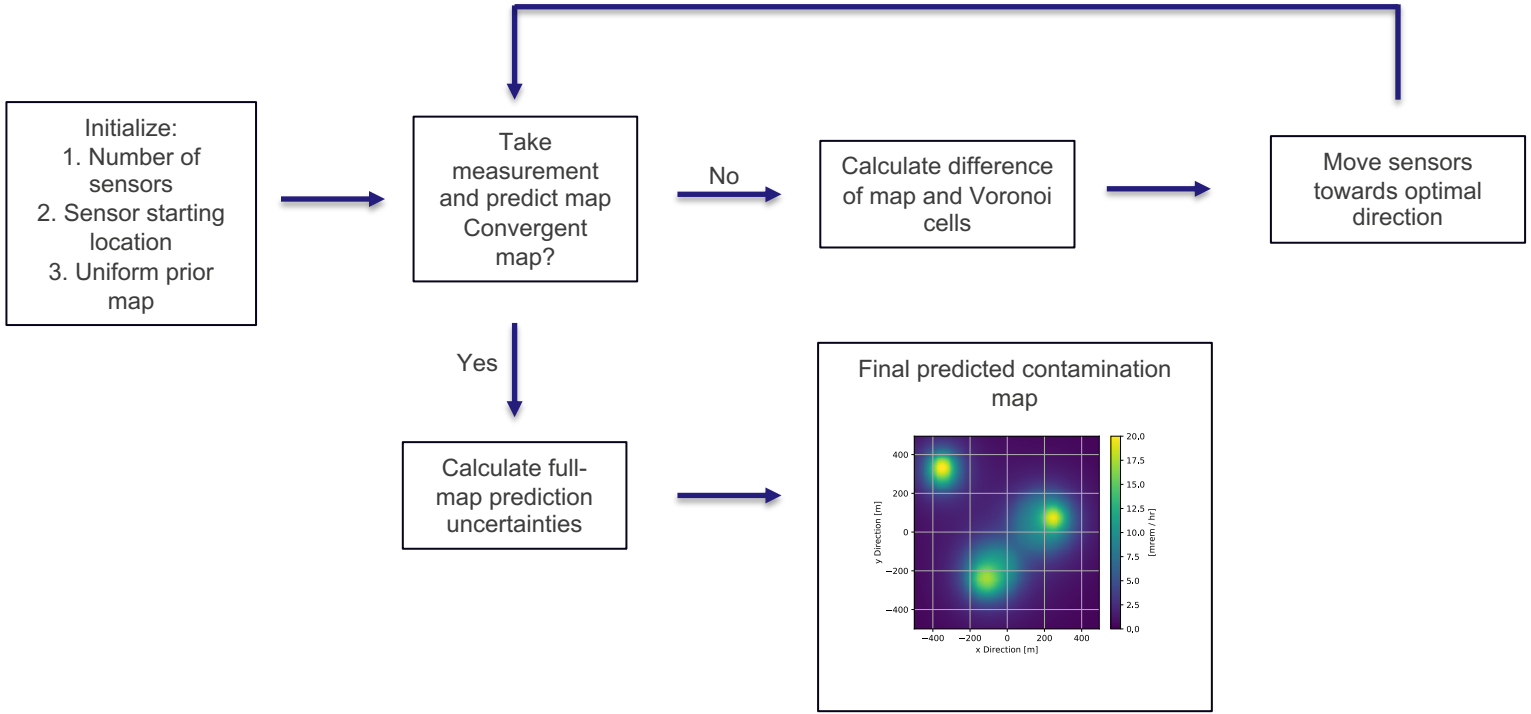


Each Voronoi cell consists of all the points within the entire area of interest whose distance to one sensor is less than or equal to its distance to any other sensor

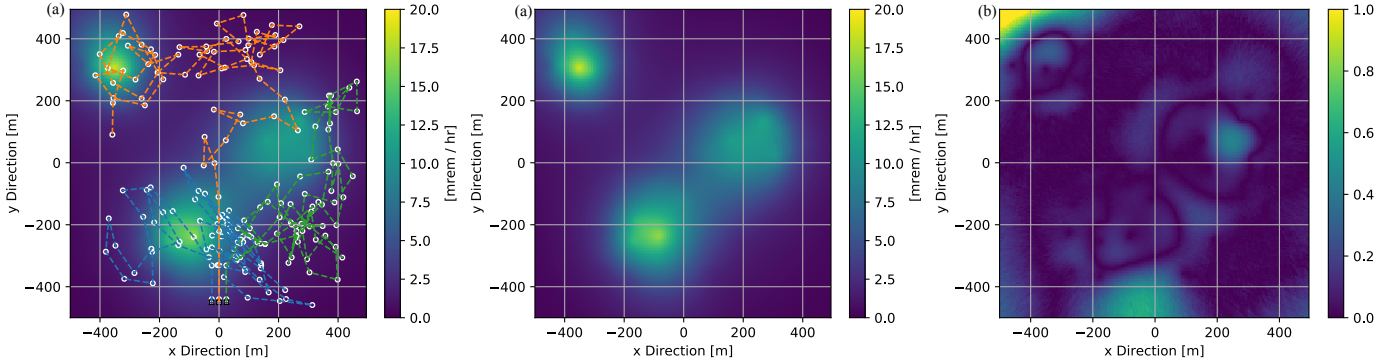
Difference of prior and current map informs direction of sensor movement

Goes in direction of largest difference

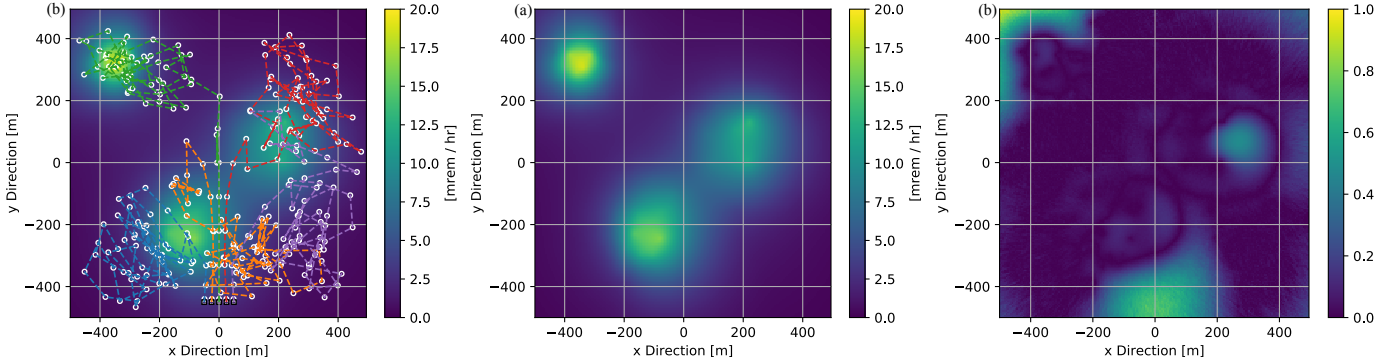
Optimal motion planning procedure



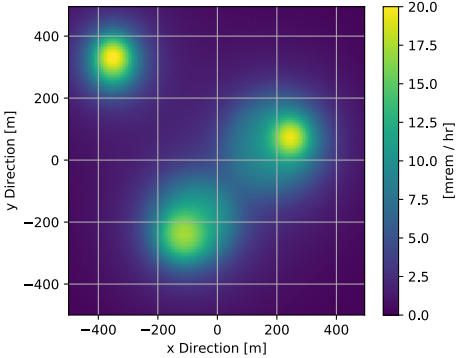
Simulation results



Three-sensor GPR survey routine

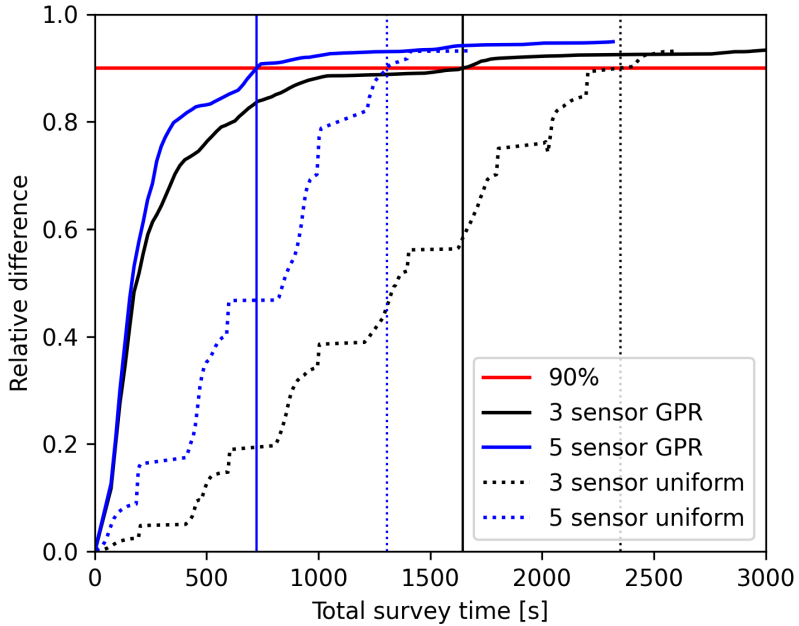


Five-sensor GPR survey routine



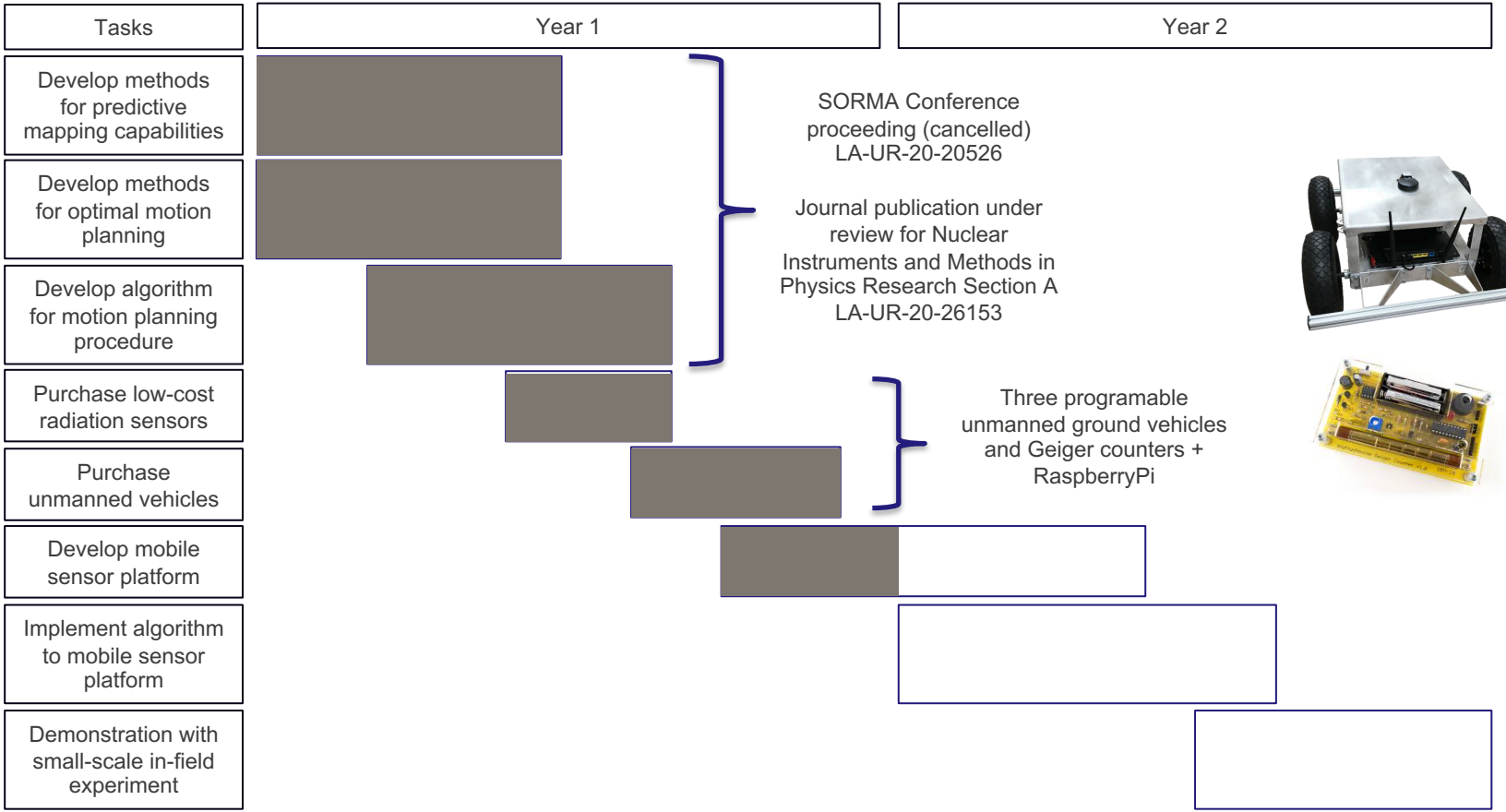
True simulated contamination in MCNP6.2

Comparison to uniform survey routine



GPR-based motion planning reaches convergent map faster than uniform survey

Project timeline and milestones



Year 1 outcomes and Year 2 projections

1. Developed fully autonomous motion planning procedure for mobile sensor platforms
2. Demonstrated in simulations the improvements in speed of producing contamination map compared to uniform survey routines
3. Procured necessary equipment

Year 2 will focus on preparing a small-scale in-field demonstration with acquired unmanned ground vehicles and radiation sensors of different types

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DTRA white paper prepared “Predictive Mapping Of The Nuclear Battlefield From Sparse Measurements By Autonomous Platforms” (BAA HDTRA1-18-S-0002)

Space-based cognitive sensing applications

Autonomous exploration for planetary science

Awarded Disruptech Entrepreneurship Postdoctoral Fellowship to investigate feasibility of transitioning technology to industry